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ABSTRACT

To gain a greater understanding about how people comprehend a set of directions, a macro-level research approach is needed. Researchers must first decide on the domain of activity that is to be investigated. In our society instructions are used for building things from parts, disassembling things, determining the functional characteristics of things, operating something, or carrying out some action. Researchers should first think of the carrying out of the task as a problem faced by the subject, and then think of the act of carrying it out as proceeding through a problem space. The structures of the problem space for different tasks are probably not only very different, but different in specifiable ways. Thus, a taxonomy of tasks could probably be developed based on the characteristics of the problem space of their solution. Instructions are ways of providing information that can place additional constraints on the decisions being made in carrying out the tasks. Researchers should attempt to characterize what sorts of instructions place what sorts of constraints on particular categories of subjects, and then try to understand why this is so. This requires three tasks: developing a means of characterizing decision points, identifying the types of information necessary to constrain choices at these points, and providing knowledge on the most effective means of communicating these types of information. Finally, the researchers should examine the characteristics of the instructions that influence the likelihood that the information provided will actually be used. Such information can help to build a knowledge base for those who have responsibility for developing instructions. (HOD)

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A Framework for Research on the Comprehension of Procedural Texts and Pictures

(Reactions to papers presented in 1982 IRA session on Comprehension of Procedural Texts and Pictures)

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What I want to do in the next few minutes is to try to give an overview of the issues that need to be researched concerning the comprehension of procedural picture-text combinations. I hope that this will help to place the studies that have been reported here into a larger context, and perhaps even suggest future directions.

I assume that the goal is to gain a greater understanding about how people comprehend a set of directions explaining how to do something, how to carry out some set of procedures or how to achieve some goal. One of the main motivations for such research is to develop a knowledge base that will help those who have responsibility for developing instructions, whether they be on lawn-mower repair, constructing a swing set, or operating a rocket launcher. The importance of clear instructions varies with the task, of course. The fact that I had to disassemble part of a swing set in order to add a piece that should have been included earlier in the sequence was just a 45 minute inconvenience, though one I would much preferred to have avoided. However, my daughter is still riding her plastic tricycle with the front wheel backwards because, once the parts were assembled they could not be taken apart without breaking them. Incorrectly placing jumper cables on your battery can put your car out of commission and result in a considerable repair bill. While these are the kinds of consequences we have in everyday life which result from poor instructions, they are small compared to those which can result from mistakes in nuclear power plants and with military equipment. Thus, the consequences of poor instructions range from inconvenience to substantial cost to outright disaster. As technology advances, mistakes have more and more severe consequences. And so it becomes more and more important that we understand how to make instructions clear and effective. Furthermore, while there is an increase in the use of audio-visual equipment of various types for instruction (slide presentations, filmstrips, computer instruction, etc.) it will probably always be the case that the inexpensive medium of paper and ink will be the most pervasive vehicle for communicating to people how to do things. Thus, research that can improve this form of communication is significant.

As in conducting research on any area, one must decide first what is the domain of activity that is to be investigated. I have not seen a thoughtful survey of the types of tasks for which instructions involving pictures and text are typically used in

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our society. A taxonomy could probably be developed, and would likely include instructions on:

1. building things from parts,
2. disassembling things,
3. determining the functional characteristics of things (for example, diagnosing a problem shown by a piece of equipment),
4. operating something,
5. carrying out some action (such as serving a tennis ball or using a cross-cut saw properly).

Some instructions are for more complex activities, such as repairing a lawn mower, which may include three tasks: diagnosis, disassembly, and assembly. I do not know whether anyone has tried to determine whether these different types of tasks require characteristically different types of instructions.

In order to conduct research, it is necessary to select certain tasks to study. Thus, it is necessary to decide on the subdomains from which to draw the tasks to use. The Cornell group has focused on studying tasks involving assembly, using parts that are relatively uninformative concerning what their relationships are likely to be in the finished product, and providing instruction on how to carry out the assembly. This research has been underway now for several years under the direction of Dr. Marvin Glock, and beginning with the work of David Stone which led to his dissertation.

Given that a specific task is selected, it seems appropriate to think of the carrying out of the task as a problem faced by the subject, and to then think of the act of carrying it out as proceeding through a problem space. At each point in the process, the subject is faced with a decision about what to do next, and has a range of choices. The process of assembling the final object, then, is viewed as the process of making a series of choices, and the particular sequence taken by the subject is regarded as the path he took through the problem space. From this perspective, then, it would be possible to analyze the problem space for a particular task in order to identify the range of decision sequences (or action sequences) which lead to successful performance, and those which do not. From this perspective, it should be possible to characterize both the similarities and differences among a group a subjects in the paths they take.

In the loading cart task, there is actually a large number of paths that lead to a solution. One can start with building the back or with building the platform, for instance. However, there are some definite constraints. Building the back would be

difficult in any other sequence than by assembling the columns prior to putting the flat pieces in. Furthermore, it is necessary to assemble either the back or the platform before adding the wheels. Examining the problem space for the construction of this object would probably reveal a hierarchical structure. There are important components of the task (constructing what Stone called "subassemblies") that can be built via a variety of sequences, but, once completed, join with other subassemblies in only one way. The point I wish to make here is that the structure of this problem space for different tasks is probably not only very different, but different in specifiable ways. Thus, a taxonomy of tasks could probably be developed, based on the characteristics of the problem space of their solution. Differences in tasks might include the average number of choices at the decision points, the degree of hierarchical structure, degree of linearity in the structure, etc.

Now with this ideas in mind, it is possible to talk about the nature of instructions. I will define instructions as any means of placing added constraints on the decisions in the problem space. The phrase "added constraints" is used to recognize the fact that, at any decision point, the partially-built object and the remaining parts place constraints on the possible next actions. For instance, a bolt is only likely to be used next if the object, as constructed so far, has an appropriately-sized hole in it.

These natural constraints depend partially on what the objects call to a person's mind. This is the point Marie Knowlton is trying to deal with, within the present context. The line of research she is conducting explores a form of functional fixedness; how it is that the orientation of a part might influence what it calls to a subject's mind upon looking at it, and thus how its presence might influence the decisions a subject is likely to make in the building sequence. Thus, she implicitly suggests that the orientation of a part can either enhance or reduce the likelihood that a particular action will be taken, either by enhancing or reducing the likelihood that looking at it will call to mind the function it must play in the task at hand. How powerful an influence this has in actually building something is not known, of course.

One point that is important to keep in mind when looking at eye movement records as a subject examines pictures, as Knowlton is doing, is that past research indicates that the eyes tend to be drawn to regions of greater uncertainty, often reflected in greater stimulus complexity. Thus, the fact that Marie's subjects tended to spend more time fixating on the handle of the cup, where there is more detail, than on the large open spaces consisting of the bottom and top of the cup, may be simply another example of that tendency. Whether subjects' preferred fixation locations on a simple figure tend to be related to the function they most readily see it playing is a question that will

require a careful analysis of the eye movement records produced by her other pictures.

The instructions, then, are simply ways of providing information that can place additional constraints on the decisions being made in carrying out the task. The researcher's job is to attempt to characterize what sorts of instructions place what sorts of constraints on particular categories of decisions, and perhaps for what particular categories of subjects, and then to try to understand why this is so. This requires three things: first, it requires that we develop a way of characterizing a particular decision point in a manner which summarizes the nature and perhaps range of likely options available, the choices that might be taken. This, then, is the range of possible choices that must be further constrained by instructions. Second, it is necessary to develop an understanding of the type of information necessary to place constraints on different types of options and ranges of options. Third, it is necessary to understand the ways that different types of information can be provided in the instructions most effectively. I would like to make a few comments now on each of these three necessities.

First, developing a way to characterize a particular decision point. After having carried out action X, what comes next? It is necessary to develop a language, a way of describing a decision point. What options are available, and what is their nature? How many of these are actually appropriate? Are the appropriate alternatives the ones that are likely to be selected by subjects at this point? If the designer of instructions is to be able to select from a range of possible instruction types to constrain this decision, he must first be able to perceive and remember how the decision being made at this point is different from other decisions that benefit from other types of instruction. Only if these differences in decision points can be perceived, is it possible to selectively choose alternative forms of instruction. A descriptive language for characterizing the decision points would assist a designer to be sensitive to important distinctions, and would provide a means for encoding critical aspects of a decision point that should be taken into account in selecting an approach to providing instructions, if they are necessary. The development of such a language would probably begin with a careful analysis of many decision points, attempting to describe them in as much detail as is practical, given that the desire is to have descriptors that are generalizable. Later, it will be necessary to determine which of these distinctions are useful for helping make choices of instructions, and non-useful distinctions can be dropped.

The second task of the researcher is to find what types of information are needed to constrain different types of decisions. Different types of information are undoubtedly needed to help a person select the right size bolt, or orient a part to fit properly onto the previously-built subassembly, or to begin

construction of the right subassembly next. Different decision points in the problem space undoubtedly require different types of information to appropriately constrain the choices available.

Given that it is possible to properly describe a decision point, and from that to be able to identify the information needed to constrain the choices, the third problem is to determine the most effective means of communicating the different types of information. This research area obviously assumes that some kinds of information are best communicated via text, and others via pictures. Text can very effectively communicate some types of information that may be more difficult to communicate through still pictures. For instance, "Left up the cover flap and insert your index finger into the hole underneath. Place your finger tightly against the nut, so that it will not turn as you tighten the screw." This would be very hard to describe through a picture. Text seem particularly useful in communication certain types of sequence, reasons for doing things, warnings of possible dangers or things to watch out for, how things should feel, etc. Other types of information is communicated most easily through pictures. For instance, the following is rather awkward in text: "First grasp the nut that is behind the coil and just to the right side of the rubber hose that enters the motor about 2/3 of the way back and half way up on the driver's side. Turn it clockwise until the arrow engraved on it points to the arrow point on the engine that is immediately below and to the right of the nut itself." This could undoubtedly be communicated much more easily and precisely through pictures. In general, such information at spatial localization, identification from among similarly-shaped objects, direction of action and spatial relation to other objects can probably be communicated more effectively through appropriate pictures. Work aimed at characterizing efficient means of communicating information of different types lays a groundwork both for a theory of human use of picture-text information, and for the selection of appropriate communication methods when designing instructions. Developing a well-justified taxonomy of types information that instructions sometimes need to communicate, and the effective means of communicating them, are important jobs for researchers in this area.

Critical tasks in this area, then, are to develop a means of characterizing decision points, to identify the types of information necessary to constrain choices at these points, and to provide knowledge on the most effective means of communicating these types of information. This can lay the knowledge base to assist someone in developing instructions for aiding people to proceed through a problem space efficiently and with minimal negative consequences.

With this in mind, it is possible to put George Bieger's work in perspective. George has attempted to identify types of information that are particularly widely needed in constraining subject's decisions as they construct objects. He suggests four

types of information as critical: Inventory information (which part to use next), operational information (what act to perform with it), spatial information (where in relation to previously-used parts should this part be used), and contextual information (what is it that is being constructed). He suggests that when there is less of these types of information, construction takes more time and there is a great increase in the number of errors made in the process. It should be noted, however, that his instructions likely included a certain amount of temporal information, as well, since they undoubtedly constrained subjects to do some things prior to others. Whether other of his types of information are needed to place appropriate constraints on particular decisions during construction undoubtedly depends on the nature of those decisions.

Thus, Bieger has suggested some of the types of information that are particularly important in constraining the decisions made during the construction task. From the perspective I have described, however, we would like to see a much more detailed analysis of his data. How effective were pictures vs. text in communicating these different types of information. How did these different types of information constrain individual decisions and actions of various types, both in terms of time required to carry them out, and likelihood of taking a wrong alternative. I hope that he plans to follow up this work in a more detailed manner. I am not convinced, for instance, that all decisions need instructions that provide all these types of information. This is so simply because at times the constraints resulting from the object so far constructed and the parts yet to be added provide enough constraint that this is unnecessary.

I have one concern about the analysis of the data presented in Bieger's paper. There is actually nothing in the analysis that would convince a skeptical reader that the four types of information proposed are critical, or that others are not. We know that, when the conditions of the experiment are partitioned in a certain manner, one set results in better performance than the other. This is not clear evidence that those task characteristics common to the set producing better performance are all critical, and other characteristics are not. I strongly suspect that the grouping of the conditions was done on the basis of the pattern of data itself. Perhaps in examining the means from the different groups, it seemed quite clear that, so long as those types of information were present, performance was consistently high, regardless of the manner in which they were presented (pictorially or textually), and that when any of them were missing, performance was lower. Some sort of presentation that showed that pattern would in fact be more convincing of the paper's main thesis than is the analysis of variance, as presented.

I should make it clear that in the framework I described earlier, I did not mean to suggest that there needs to be instructions for every decision point in carrying out a task, nor

even that instructions can only be directed at individual decisions. In fact, the picture of a completed object (Bieger's contextual information) may serve as a strong constraint on many decisions, eliminating the need for specific additional instructions at many decision points. The goal of the instruction is to apply just those additional constraints that are needed to allow efficiency in making choices, and to reduce the likelihood of taking wrong alternatives or less effective alternatives. Whether the best way to do this is to try to use precise instructions at each point to specifically guide the decisions, or to apply more general constraints and allow a range of appropriate choices to the subject, probably depends on the task. Whether one is a generally more effective approach must be a matter of study. In communication generally, we try to achieve appropriate level of specificity. The person who tries to be too specific is often difficult to listen to and sounds pedantic and boring. In the same way, overly detailed verbal instructions are likely to go unread, and overly detailed pictures may fail to constrain because they do not distinguish between the critical and less important information.

The final aspect of research in this area has to do with the manner in which subjects use the instructions as they carry out their task. Providing access to carefully-designed materials is no guarantee that they will be used appropriately, though it is likely that poorly-designed instructions will soon be ignored by even those whose initial propensity is to use them. Thus, it is critical to examine not only the information necessary to constrain decisions, and the form in which this can most readily be supplied, but also characteristics of the instruction which influence the likelihood that the information provided will actually be used. And this may differ for different groups of subjects. This is the area dealt with in Fran Schorr's paper. She was interested in two aspects of the subjects' strategies: first, their general approach to the task, including the way in which they used the instructions, and second, how they detected and dealt with errors. These differences may be related to subjects' spatial abilities, general reasoning abilities, and mechanical aptitude, for example.

Suppose that we do find aptitude-treatment interactions in this area; that is, that different subjects could benefit most from different types of instructions. In providing people with instructions in the real world, it is unlikely that we would have the benefit of tests of individual differences in order to know which of several instructions to give to them. Some accommodation can be made to a person's knowledge level, at times. Computer manuals, for instance, frequently include sections for the novice which more advanced students are advised to skip. However, it is unlikely that different instructions will be prepared for people differing on other dimensions, since it is unlikely that the person giving out the instructions will have personality or cognitive ability data on those with whom he deals. Thus, in

reality, once we know the differences in the way different people use the instructions (and hence what information they are likely to use vs. miss), this knowledge is most likely to be used to sensitize the developer to the types of problems different subgroups of people are likely to encounter in the using the instructions. This knowledge may help in the design of the instructions to try to minimize the likelihood of costly errors which typically result from different strategies to the task.

I have tried to describe a perspective in which research on comprehension of procedural text and picture combinations can be studied, and to use this to place the work of the Cornell group in a larger context. This perspective suggests that it is probably not useful to ask whether, in general, pictures or text are more important in instructions, or even whether some kinds of pictures or texts are more useful. Rather it focuses on the fact that carrying out a task actually consists of making a series of decisions, and that the information needed to constrain different decisions varies. Thus, which sorts of information or information sources proves to be more important for a given task will depend on the characteristics of those decisions. It suggests that, rather than trying to begin by asking global questions, we will, in the long run, be more productive if we focus on a detailed analysis of the types of decisions people are faced with in carrying out tasks, the types of information necessary to appropriately constrain choices in these decisions, and how such information can be effectively communicated. It argues, then, for taking a micro-level approach to this research in order to develop the concepts and principles that are needed by instruction designers to give guidance in how to analyze a task and identify the kind of information needed by those likely to try to carry it out. It is obvious that there is a great deal of work to be done, and the benefits of careful research in this area can have practical as well as theoretical benefit. I hope that some of the students who have been involved in this research at Cornell will have a desire to continue a programmatic research effort in this area as they take positions elsewhere.

Reference

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"Information Content of Text and Pictures and Its Effect on Comprehension." Bucknell University, 1982.